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METALLIFEROUS LATERITE IN NEW CALEDONIA

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A recent paper on lateritic ore deposits by W. G. Miller[1] gives among other matters an account of the composition of the nickel- and cobalt-bearing laterite of New Caledonia, but does not call attention to the physiographic relations of the laterite, probably because the physiography of the island has been little discussed in published articles. Even the manifest evidence of submergence given by its embayed shore line has hardly been mentioned by the students of its geology. The mature sea cliffs, which usually cut off the hard-rock highlands along the northeastern coast and which frequently descend, except for narrow fringing reefs, into ten or twenty fathoms of water, contrast strongly with the rounded hills and sloping lowlands of weaker rocks that dip gradually under sea level along the southwestern coast; but the contrast has only been treated empirically if at all in accounts of the island. Furthermore, the form of the northeastern cliffs, the depth of the reef-enclosed lagoon in front of them, and still more the form of the embayed valleys that interrupt the cliffs, all taken together, indicate that the cliffs were cut by waves while the island stood several hundred feet higher than now, and that this higher stand occurred during a subrecent period of the physiographic development of the island when the northeastern coast must have been unprotected by coral reefs for a time long enough for the cliffs to be worn back several miles; but these physiographic contributions to the historical geology of the island, not being attested by fossiliferous stratified deposits, appear to have been overlooked. As long as elements so important as these in the historic geology of New Caledonia land forms remain unstated, the origin of its superficial ore deposits will necessarily be unsolved.

The most significant features in connection with the ore deposits are the highlands on which they lie. Although the greater part of the mountainous island is of irregular form and varying altitude, there are certain districts,

particularly those occupied by serpentine rocks, which are characterized by rolling highlands of moderate relief at altitudes of 600, 800 or 1000 feet. These seem to be elevated peneplain areas; they are trenched by relatively steep-sided valleys, and are adjoined either by surmounting residual mountains, presumably formed of more resistant rocks, or by the lower hills and lowlands of the southwestern coast where weaker rocks prevail. The erosion of the subdued southwestern lowlands and of the narrow valleys in the highland areas has evidently been accomplished after the partial peneplanation of the island and its subsequent elevation, and during the same period of higher stand that witnessed the cutting of the sea cliffs along the northeastern coast, previous to the recent submergence by which the shoreline was embayed. The amount of the recent submergence may well have been from 600 feet or more; the previous upheaval of the northeastern side of the island, before its cliffs were cut, was probably at least twice as great, for the sea-cliffs today, in spite of being partly submerged, not infrequently still show 600 or 1000 feet of their height above water. The absence of all consideration of these inferences in the geological accounts of New Caledonia affords a striking illustration of the contrast between the older geological philosophy that based its theories only on the structure of rocks and their mineral and fossil contents, and the newer philosophy of geology which broadens the older one by adding thereto a reasonable consideration of surface forms and their evolution.

During my relayed trip around the island on three trading steamers, supplemented by local sail-boat excursions, in June and July, 1914, the rolling highlands were recognized as elevated peneplains at many points on both coasts. Where their vegetation is scanty, as is often the case, the soils of the highland slopes are laid bare in rain-washed gulleys which disclose their varied colors, dark or black at the surface and usually a strange mixture of vivid reds and ochres beneath. At certain points the open workings of the highland laterite mines were seen, and at one harbor where a steamer touched for an afternoon I had time to climb the slopes and inspect the excavations. The residual nature of the deposits was manifest enough. The boulders, referred to in Miller's paper as lying at the bottom of the loose deposits and as affording a rim or coating that is scraped off and added to the ore pile, are perhaps partly concretionary in origin, but some of them appeared to be incompletely decomposed rock kernels lying almost in place within a matrix of more disintegrated material. It is significant that the abundant hill-side detritus is not worked; ore of paying richness and quantity seems to be limited to the highland areas. It is further significant that, as is usual in such residual deposits, analyses of the highland ore deposits show a much higher percentage of nickel and cobalt than is found in the underlying serpentines.

In view of all this it seems reasonable to infer that the ore deposits are the result of surface enrichment by leaching and concentration during the later stages of the above-mentioned cycle of peneplanation, and that they have been undergoing removal rather than further accumulation and enrichment in the

later cycle of erosion introduced by elevation; the removal thus initiated is still continued in spite of the still later subsidence.

The general sequence of changes by which the present form of the island has been evolved from a subcontinental land of Tertiary or earlier time may be outlined as follows. A composite land mass of large, perhaps continental, extent, consisting hereabouts of deformed crystalline and Mesozoic rocks, was eroded to mountainous or moderate relief, *AB*, in the background block of figure 1; it was then reduced in area by down-warping, probably in tertiary time, whereby the surviving land area must have gained an embayed shore line, *C*, *D*, as in block 2. If coral reefs had previously existed around the border of the larger land, they must have been drowned by rapid submergence, for the

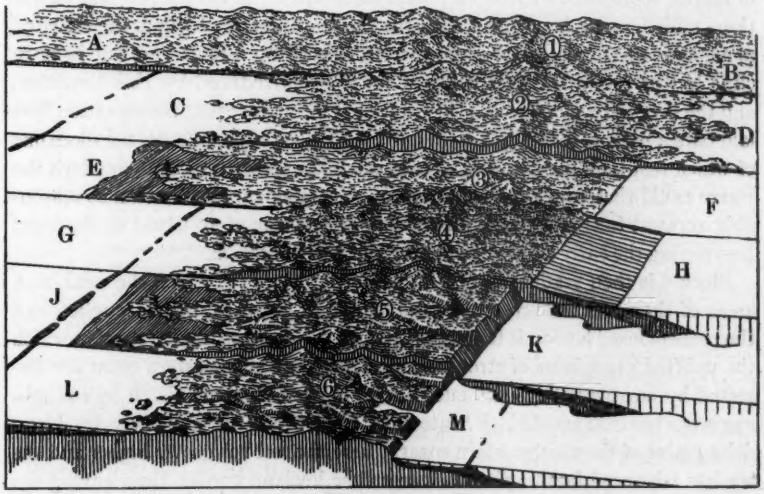

FIG. 1. THE PHYSIOLOGICAL DEVELOPMENT OF NEW CALEDONIA

adjoining seas are very deep. New reefs may have been formed in the later stages of submergence, enclosing a lagoon, *C*.

The reduced island of block 2 must have stood still long enough to suffer reduction to small or low relief, except in its areas of most resistant rocks, as in block 3; the serpentine areas were mostly reduced to peneplains at this time. The embayments formed in the shore line at the beginning of this cycle of erosion were presumably in time filled with deltas that advanced into the reef-enclosed lagoon, as at *E;* the deltas may indeed have grown so far as to overwhelm and smother the reef, whereupon it would be cut away by the waves which would in time attack the worn-down land, retrograding its peneplains in low cliffs and spreading the detritus from them and the rivers on the shallow floor of the adjoining sea, *F;* for this change from a reef-fronted and prograded coast of submergence in an early stage of an erosion cycle that

had been introduced by warping to a reef-free and retrograded coast in an old stage of the cycle is a most natural consequence of a long stationary period in the history of an island in the coral seas.

Another warping is then inferred, chiefly because the change from the subcontinental land of block 1 to a narrow island adjoined by deep seas on both sides, is not likely to have been accomplished in a single period of deformation. This warping must be supposed to have affected the island unsymmetrically, as in block 4, probably drowning any previously formed barrier-reefs along the southwestern coast, and re-embaying the shore line there, where a new barrier reef, *G*, would be developed, but this last point is not essential; at the same time the northeastern coast appears to have been uplifted, so that a coastal plain of marine sediments, such as may have accumulated in the shallow sea, *F*, was there added, as at *H*. The reason for the last inference is that the elevated peneplain areas along the northeastern side of the island were cut back in cliffs by the sea in the early stage of the cycle introduced by this elevation; and the simplest way of accounting for this is to suppose that the elevation here laid bare a narrow coastal plain, covered with loose sediments, on the shore line of which reef-building corals could not establish themselves, and on which the waves could therefore work unimpeded. No other supposition can so reasonably account for the abrasion of cliffs along one side of an island in the coral seas during the early stages of a subrecent cycle of erosion.

Block 4 is then gradually transformed into block 5, in which the weak-rock areas of the southwestern coast are again worn down to moderate relief, and the reef-enclosed lagoon is largely filled with delta plains, as at *J;* and in which the uplifted peneplains of stronger rocks along the northeastern coast are dissected by narrow valleys and cut back in high cliffs, as at *K*. A recent submergence has converted block 5 into block 6, drowning the previously developed delta plains of the southwestern coast, where the reef has grown higher and the sea has advanced farther than before on the lowland border, thus leaving the broad lagoon, *L*, of today between the young shore line of submergence and the barrier reef; the same recent submergence has partly drowned the cliffs of the northeastern coast, so that their valleys are now beautifully embayed, and a barrier reef has grown up from the sea bottom in front of them, as at *M*. It is chiefly upon the highland peneplains back of the cliffs of this coast, and upon similar highland areas which occur along the northwestern half of the other coast, that metaliferous laterites occur.

Abundant variations on the earlier stages of the foregoing scheme may be proposed. The changes here outlined are probably much simpler than the changes that have actually taken place, and some of the changes here indicated are very uncertain. For example the cutting back of the embayed coast, *D*, in block 2, to the low cliffs, *F*, of block 3, is by no means assured; but the unsymmetrical warping by which block 3 was transformed into block 4 seems to be essential as a means of reasonably providing for the development of sea cliffs in a relatively early stage of the cycle of erosion on one side of the island

where the rocks are hard, while no cliffs are developed on the other side of the island, even though the cycle of erosion on the weaker rocks that there prevail advanced in the same measure of absolute time to a late stage of development, when reef extinction and retrogressive abrasion are expectable occurrences. The prevention of cliff development on the southwestern coast is favored by assuming that the submergence which lowered block 5 to block 6 was caused by progressive subsidence. In any case, the general submergence by which block 5 is changed to block 6 is easily demonstrated. It is therefore in view of some such geologically modern sequence of moderate deformation and prolonged erosion as is here sketched, uncertain and shadowy in its earlier stages, better certified in its later stages, that the development of the ore-bearing laterites must be explained.

The enrichment of the present ore deposits could not have begun on the serpentine areas in the immature stages of the earlier cycle of erosion in which block 2 was worn down to block 3, for at that time the valley-side slopes, profiles 1, 2, figure 2, were steep enough, just as they are in the immature stage, profiles 1′, 2′, of the present cycle in the serpentine areas, to allow the

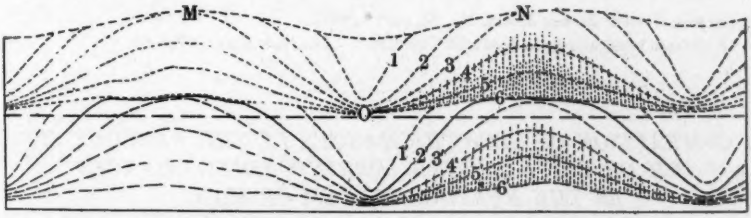

FIG. 2. RELATION OF ORE-BEARING LATERITE TO TWO CYCLES OF EROSION

removal of disintegrated rock about as fast as it was weathered. Even during the mature stage, profile 3, of the earlier cycle, removal rather than accumulation must have prevailed; but as the later stages of the cycle were reached, soil removal from the subdued hills, profiles 4, 5, between the wide-open valleys must have been much slackened; the thickness of the disintegrated materials there occurring and with it the surface enrichment of the metallic ores by downward concentration must have thenceforward increased as the subdued hills were worn down to the gentler and gentler gradients of old age, as in profile 6; and the area on which concentration was important must have been on the low swells between the broad valleys. If these inferences are correct, it follows that the nickel and cobalt content of the greater part, *MNO*, of the primeval rock mass has been carried away and deposited on the adjoining sea floor, and that the deposits now worked contain chiefly the concentrated savings from only a quarter or a sixth of the primeval total, shaded in the upper half of figure 2. This explanation traverses Glasser's supposition[2] that the serpentine masses have not been much eroded; for in view of their form alone, apart from the evidence of erosion given by ore concentration, that supposition seems untenable.

Again, the submature or mature main valleys, profile 2′, of the prentcyclees presumably excavated beneath the wide-open old valleys of the earlier cycle, have not as yet encroached greatly upon the ore-bearing part of the inter-valley highlands, profile 6. The encroachment and removal will be greater and greater as the main valleys of the present cycle are widened, profile 3′, (the recent submergence is not indicated here) and as branch valleys are extended headward into the highland by retrogressive erosion. Still later, profile 4′, the highland surfaces of the earlier cycle and their residual laterite cover will be completely worn away; but finally, when old age is again approaching, profiles 5′ and 6′, new deposits will again be formed by rock disintegration and ore concentration on the subdued and lowering inter-valley hills of the future, just as happened in the past.

The superficial laterite ores of the serpentine highlands in New Caledonia therefore seem to be local as to area of development and intermittent as to time of origin and duration of occurrence. The same relations presumably obtain in a general way regarding the limonite and bauxite deposits of our Appalachian valleys.

[1] *Report, Ontario Bureau Mines*, No. 26, part 1, 1917.

[2] Richesses minérales de la Nouvelle Calédonie, *Ann. des Mines*, 1903–04.

A COMPARISON OF GROWTH CHANGES IN THE NERVOUS SYSTEM OF THE RAT WITH CORRESPONDING CHANGES IN THE NERVOUS SYSTEM OF MAN

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Read before the Academy, April 23, 1918

For a number of years the albino rat has been used for the study of growth changes which occur in the brain between birth and maturity.

As occasion offered, the results obtained from the rat have been compared with those from man, in order to determine how far the rat might be used for the study of the corresponding problems in man.

As all of these studies were in the field of growth, and as growth is a function of age, it became necessary in order to make the cross reference, to determine the equivalent ages of the rat and man.

Two observations were available for this determination.

1. The rat doubles its birth weight in 6 days, while man takes 180 days—giving a ratio of 1 to 30 days. From this it would appear that the rat was living 30 times as fast as man.

2. Again, a rat of 3 years is very old—so that I have ventured to compare a rat of this age with a man of 90 years. Once more the rat appears to be living 30 times as fast as man.

For working purposes we assumed that 1 day in the life of the rat was equivalent to 30 days in the life of man, and that the equivalent ages in these two animals were represented by equal fractions of the span of life.

One adjustment is necessary however in dealing with the data for the nervous system. The brain of the rat at birth is less mature than that of man at birth, and it is not until the rat is 5 days old that the brain is in the same phase as that of man at birth.

In making any comparison therefore the data for the rat at 5 days of age are arranged to coincide with the data for man at birth. Using the foregoing methods, four comparisons have been made between the growing nervous system of the rat and that of man.

The first chart is for the growth in the weight of the entire brain of the rat from birth to maturity, compared with that of man. When the human brain

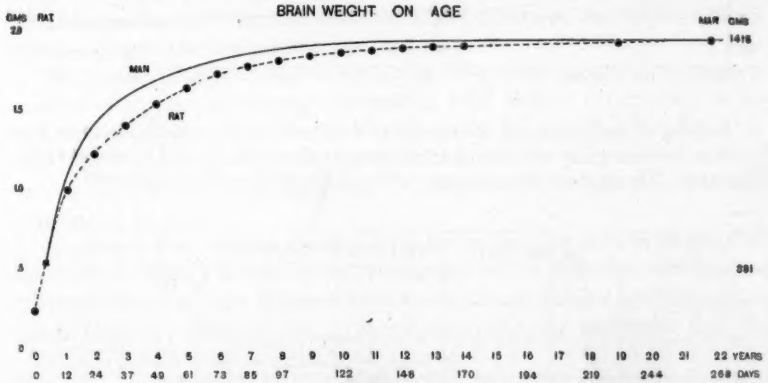

CHART 1

Showing the increase in the brain weight of the albino rat on age (broken line and dots) and compared with this the increase in the brain weight of man at the equivalent ages (solid line). The values for equivalent ages are on the same ordinate.

weights are reduced, and the comparison is made in the way described, the two graphs run well together. Thus, at equivalent ages, the brain in these two forms has undergone nearly the same degree of enlargement.

Chart 2 shows the percentage of water in the rat's brain at different ages. The graph indicates a rapid, followed by a slow loss of water, with advancing age. I have found only four corresponding records for man, namely at birth, 2 years, 9.5 years and 25 years, and these are entered by the heavy black dots at the equivalent ages on the graphs for the rat. The coincidence is good.

It has been determined that this loss of water is due to the progressive accumulation of myelin in the nervous system (Donaldson, '16) and the inference is therefore justified that the formation of myelin is progressing in a like manner in the two forms—only it progresses 30 times as fast in the rat.

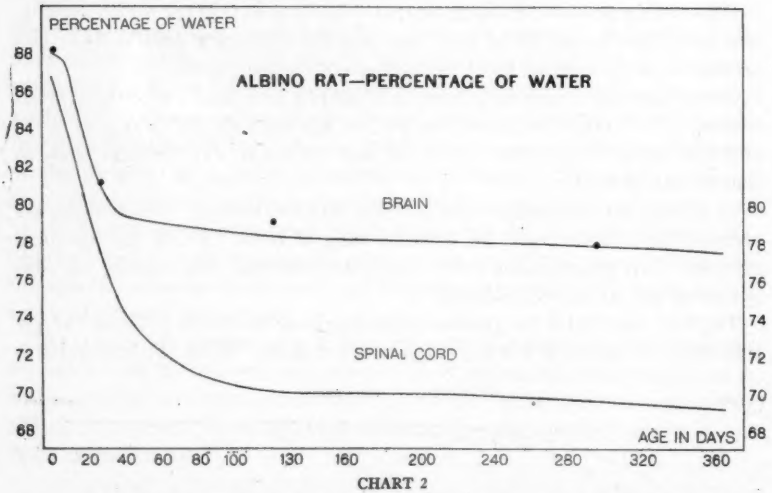

CHART 2

Showing on the upper graph the percentage of water in the brain of the albino rat from birth to 365 days. The four heavy dots represent the observation for man entered at equivalent ages. The graph for the percentage of water in the spinal cord is not discussed.

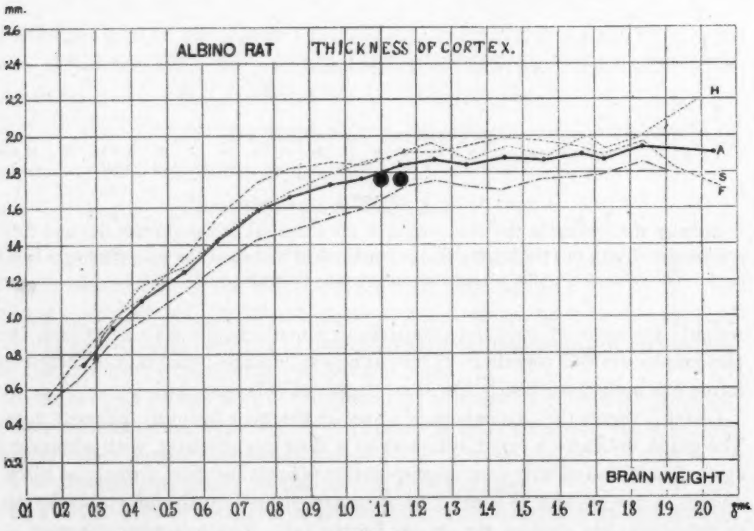

CHART 3

From Sugita '17, chart 9. Giving in millimeters the corrected thickness of the cerebral cortex of the albino rat; *H*, in the horizontal section; *S*, in the sagittal section; *F*, in the frontal section; *A*, the heavy line, represents the average of all of the measurements. The two heavy dots represent two incidental values for the human cortex—after reduction—entered at the equivalent ages.

The third instance is the maturing of the cerebellum, represented by the completion of the Purkinje cells and the disappearance of the external granule layer. In the rat these events occur between birth and 20 days of age, Addison '11. Like events occur in the human cerebellum and are completed in man at nearly the equivalent age. When the cerebellum has so far matured, locomotor control is attained in both forms, and thus this series of histological adjustments and locomotor control are accomplished at nearly equivalent ages in both the rat and man.

Finally, Dr. Sugita ('17) has just completed a study of the growth in thickness of the cerebral cortex of the rat, and the graph A in chart 3 shows that the mature thickness is nearly attained at the age of 20 days. There are at present no systematic studies on this point for man, but two incidental observations, entered as heavy dots, agree with the inference that at 15 months, the equivalent age, a like degree of completeness is reached by the human cerebral cortex, and therefore that only slight growth in the thickness of the human cortex is to be expected after this age.

There are therefore five prime events in the growth history of the nervous system of the rat, namely: (1) increase in total weight; (2) decrease in the percentage of water; (3) accumulation of myelin; (4) maturing of the cerebellum; (5) the attainment of the mature thickness of the cerebral cortex, all of which takes place at ages equivalent, or nearly equivalent, to those at which they occur in man.

It appears then that by the use of equivalent ages we have a satisfactory method for making a cross reference between the rat and man, and because the growth changes are similar in both forms, the rat may be used for further studies on the growth of the nervous system with the assurance that the results so obtained can be carried over to man.

Addison, William H. F., *Wistar Inst., Philadelphia, J. Comp. Neur.*, **21**, 1911 (459–481).
Donaldson, H. H., *Ibid.*, **26**, (1916), (443–451); these PROCEEDINGS, **2**, 1916, (350–356).
Sugita, Naoki, *J. Comp. Neur.*, **28**, 1917, (511–591).

VARIATION AND HEREDITY DURING THE VEGETATIVE REPRODUCTION OF ARCELLA DENTATA

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Communicated by H. S. Jennings, June 15, 1918

The conclusions of several investigators, that the genotype is constant in organisms that are multiplying by fission, have recently been put in question by the work of Middleton[1] (1915) on *Stylonychia* and by Jennings[2] (1916) on *Difflugia*. Middleton obtained two lines of *Stylonychia* from a single specimen

that differed constantly and markedly in their fission rate. Jennnings has shown that the descendants of a single specimen of *Difflugia* may be separated into a number of diverse lines that differ from one another in their heritable characteristics. The work herein described is part of an investigation that is being made of the species problem in the genus *Arcella* and the principal problem attacked is: Can heritably diverse lines with respect to spine number and diameter of shell be distinguished among the descendants of a single specimen of *Arcella dentata* produced by simple fission?

Arcella dentata (fig. 1) is a microscopic protozoon belonging to the lowest class, the Rhizopoda. It is as simple as any animal organism it is possible to

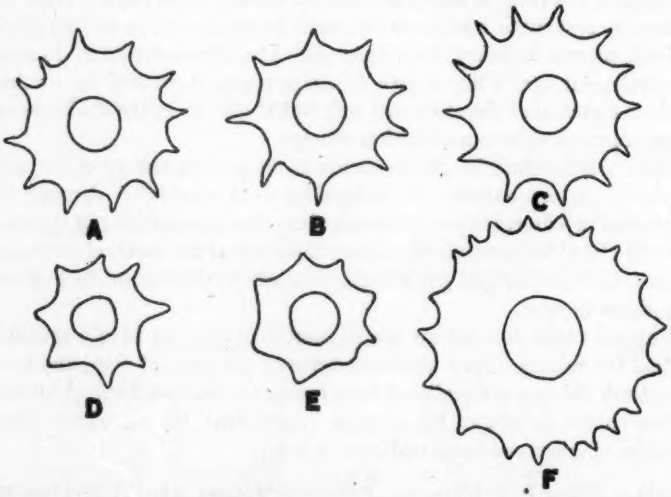

FIG. 1. OUTLINE DRAWINGS OF SPECIMENS OF *ARCELLA DENTATA* BELONGING TO FAMILY NO. 58. × 207

A, The progenitor of the entire family; *B*, a typical member of the low line *E*; *C*, a typical member of the high line *A*; *D*, the small progenitor of the line *EM*; *E*, a small specimen from the line *ED*; *F*, the largest specimen from the line *ED*.

obtain that has measurable characteristics. It varies in diameter from 73 microns to 150 microns and in spine number from 7 to 20. It multiplies vegetatively and rapidly and the characteristics of the shell are not modified by growth or by the environment, and are heritable but variable. In all, 6474 specimens were studied. Of these 171 were collected from a pond on the campus of the Johns Hopkins University at Homewood, Baltimore; 746 were reared from 70 of these specimens; and 5557 were obtained from the single specimen numbered 58. The number of generations represented by the progeny in family 58 was 69 and the average interval between generations was two and one-half days.

One hundred 'wild' specimens were first selected at random from a large number taken from the pond. These varied in spine number from 7 to 13, and in diameter from 23 to 33 units (each unit being 4.3 microns). A marked correlation (0.325 ± 0.060) was found between the spine number and diameter of these specimens.

Small families were then reared from 70 'wild' specimens selected so as to include large, small, and medium sized organisms. Seven hundred and forty-six specimens were obtained in this way, ranging in number from only 2 or 3 to 149 per family. The mean spine number of the families ranged from 10.40 to 14.07. Variations in spine number occurred among the descendants of

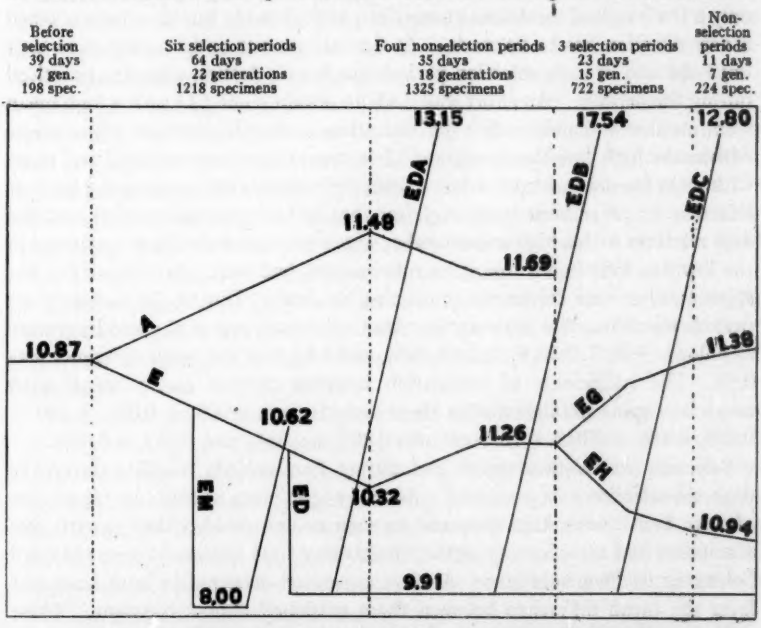

FIG. 2. DIAGRAM SHOWING THE MOST IMPORTANT HERITABLY DIVERSE LINES DERIVED FROM A SINGLE SPECIMEN OF *ARCELLA DENTATA* (NO. 58) BY FISSION

The character used was spine number. The letters indicate the designation of the lines, and the numbers are the mean spine numbers.

single specimens during fission and these variations were in part inherited. It was found that the hereditary constitution of the different families was different with respect to spine number and the conclusion was reached that a 'wild' population consists of a large number of heritably diverse families so far as spine number is concerned, and also probably as regards diameter, since spine number and diameter are closely correlated.

The main problem was next undertaken, i.e., an attempt was made to isolate heritably diverse lines from among the descendants of a single specimen produced

by vegetative reproduction. A specimen, numbered 58 (fig. 1, *A*) was chosen for this work because it was near the mean of the species in diameter and spine number, and multiplied rapidly. Figure 2 shows the principal results of the experiments. During the thirty-nine days before selection was begun 198 specimens were obtained from number 58, representing 7 generations. These varied in spine number from 8 to 13, with a mean of 10.87. Selection was then inaugurated and carried on for six periods totalling sixty-four days. During this time 1192 specimens were reared, belonging to 22 generations. The work was divided into periods so that any changes due to environmental conditions would be revealed, and also because one investigator can take care of only a few hundred specimens at one time, and when the limit has been reached a new selection has to be made. At first all parents and progeny were kept until the end of each selection period, but later selection was also practiced during the periods. An effort was made to obtain a line (*A*) with a high mean spine number and another line (*E*) with a low mean spine number. Specimens within the high line that possessed 12 or more spines were selected and those within the low line with 10 or less. Past performance was used as the basis of selection, i.e., specimens in the high line that had a high spine number and had near relatives with a high spine number were chosen, and similarly specimens in the low line that had a low spine number and had near relatives with a low spine number were chosen for continuing the lines. During the six selections periods the differences between the mean spine numbers of the two lines were as follows: $-0.07, 0.50, 0.40, 0.48, 0.84$, and 1.16, and the mean difference was 0.55. The coefficients of correlation between parents and progeny with respect to spine number during these periods were 0.060 ± 0.076, 0.220 ± 0.039, 0.186 ± 0.042, 0.185 ± 0.040, 0.403 ± 0.044, and 0.512 ± 0.039.

Selection was then stopped and during four periods totalling thirty-five days, no selection was practiced. As many specimens as could be taken care of were kept during this time and as soon as one divided the 'parent' was eliminated and the offspring kept. In this way 1325 specimens were obtained belonging to 18 generations. At first regression occurred in both lines but later the mean difference between them remained almost constant. These differences for the four periods were 0.94, 0.07, 0.41, and 0.43, and the mean difference was 0.46. The decrease in the difference after selection was stopped was probably due to the production and inclusion within the high line of low spined specimens that would have been eliminated during the selection periods and within the low line of high spined specimens that likewise would have been eliminated. Each line, however, should give rise to as many high as low spined specimens, and hence the means of each would not vary after an equilibrium had been reached and the difference between them would be permanent. The coefficients of correlation between parents and progeny within the high line during these four periods was 0.170 ± 0.027 and within the low line 0.197 ± 0.024.

The low line (*E*) was then subjected to selection in a similar way and a high

line (*EG*) and a low line (*EH*) were obtained during three selection periods of twenty-three days during which 722 specimens were produced belonging to 15 generations. The average difference between the mean spine numbers of the two lines during these three selection periods was 0.30. These selection periods were then followed by a nonselection period of 11 days during which 224 specimens were obtained belonging to 7 generations. The difference between the means of the two lines during this nonselection period was 0.44. It was concluded from these studies that two lines heritably diverse with respect to spine number, had been isolated from among the descendants of the low line (*E*).

Measurements were made during part of the nonselection periods to determine whether or not the diversities in spine number in lines *A* and *E* were accompanied by similar diversities in diameter. One hundred and twenty-seven specimens from the high line gave a mean diameter of 27.26 units of 4.3 microns each and 136 from the low line a mean diameter of 26.92 units. The difference of 0.34 unit shows that the two lines were different in diameter as well as in spine number, and that on the average the greater the diameter the more numerous are the spines. A marked correlation was found between the diameters of the parents and those of their progeny, the coefficient of correlation being 0.489 ± 0.035. A high correlation also existed between spine number and diameter, the coefficient of correlation being 0.255 ± 0.042.

Measurements were also made of the diameters of 384 of the progeny of the two branches (*EG* and *EH*) of the low line (*E*). These showed a mean difference in diameter of 0.26 unit corresponding to the difference in spine number.

These data prove that the descendants of a single specimen of *Arcella dentata* produced by vegetative reproduction differ slightly from one another in their hereditary constitution (fig. 1, *B* and *C*) and that heritably diverse lines may be isolated from among them, differing both in spine number and in diameter, and that these two characters are closely correlated. These heritably diverse lines resemble certain of the families that were reared from 'wild' specimens, and suggest that differences in the hereditary constitution of these wild specimens may have originated in the same way.

During the course of this investigation several branches were studied that arose from what seemed to be "mutations." These are indicated in figure 2 by the lines *EM*, *ED*, *EDA*, *EDB*, and *EDC*. These all appeared in the low line. Specimen *EM* had 8 spines and was only 18 units in diameter (fig. 1, *D*). Its parent had 10 spines and was 27 units in diameter. A large number of descendants (403) were reared from this small specimen, but it was found that the small diameter and lesser number of spines did not persist, but that the progeny of the fourth generation had regained the diameter and spine number of the low line from which *EM* was derived. The origin of this small specimen was therefore probably due to environmental conditions. Studies of this and certain other small specimens seem to show that it takes three or four generations for the progeny of a very small specimen to regain the normal diameter and spine number of the parental line.

The line derived from specimen *ED* is of special interest, since within it appeared the greatest diversities that were found during the entire investigation. The progeny of *ED* had a mean spine number of 9.91 and a mean diameter of 23.51 units (fig. 1, *E*). At the same time the mean spine number of the parent line (*E*) was 10.99 and the mean diameter was 27.05 units, giving a difference in mean spine number of 1.08 and in mean diameter of 3.54 units. Furthermore the differences persisted for many generations and until the line was discontinued. Specimen *ED* therefore fulfilled the conditions usually required of a mutation, i.e., it was a sudden large variation that was inherited.

From line *ED* there were derived three branches, *EDA*, *EDB* and *EDC*, that quickly exceeded in diameter and spine number any other branches in the entire family 58. The largest specimen appeared in branches *EDB*. It had 20 spines and a diameter of 40 units (fig. 1, *F*). These branches, however, soon died out for some unknown reason, although they were cultivated as carefully as possible.

The general conclusion reached is that within a large family of *Arcella dentata* produced by vegetative reproduction from a single specimen, there are many heritably diverse branches. These diversities are due both to very slight variations and to sudden large variations ('mutations'). The formation of such hereditarily diverse branches appears to be a true case of evolution that has been observed in the laboratory and that occurs in a similar way in nature.

[1] Middleton, A. R. J. Exp. Zool., 19, 1915. (451–503.)
[2] Jennings, H. S. Genetics, 1, 1916, (407–534.)

THE IMPORTANCE OF NIVATION AS AN EROSIVE FACTOR, AND OF SOIL FLOW AS A TRANSPORTING AGENCY, IN NORTHERN GREENLAND

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Nivation and solifluction, two closely related and important physiographic processes of Arctic lands, are perhaps nowhere better illustrated than in those coastal areas of northern Greenland not covered by the permanent ice-cap. The climate and the topography are favorable to the high development of these processes; the rather heavy snowfall that melts gradually during the short summer promotes the work of nivation; and the high relief, with numerous small plateaus and generally steep slopes, affords opportunity for the action of solifluction. The presence of an 'ice-table' everywhere, not deep below the surface, is an added favorable condition. As a consequence

nivation and solifluction attain a degree of importance in northern Greenland not generally appreciated.

Nivation is the process by which quiescent neve effects the disintegration of rocks, and the destruction of some land forms, and the formation of others. In this process the snow itself produces very little, if any, effect; it is the water from the gradual melting of the snow that does the work. The melting must be so slow and gradual that the water does not escape by surface run-off, but soaks into the layer of rock fragments or soil above the ice-table, and then seeps slowly downward and outward from its source.

Nivation is assuredly most effective in regions of pronounced relief, and strong and variable winds, conditions prevalent in Greenland. Under such conditions, the snow does not lie as a mantle of uniform thickness, but is piled up in drifts of various kinds. For the sake of clearness, I have classified these drifts into two, or three, rather distinct divisions, more or less characteristic of the kinds of localities in which they are found. These divisions are (1) *dome-shaped drifts*, formed on the more or less uneven tops of plateaus, on the small plain areas, and on other relatively level surfaces; (2) *piedmont drifts*, formed along the foot of extended cliffs, or series of cliffs; and (3) *wedge drifts*, formed in gullies and small gorges near the top of cliffs.

The *dome-shaped* drifts vary in size with the size of the plateau or plain surface upon which they lie, and with the strength and character of the winds that blow over. On the small segments of a plateau surface dissected by gullies or stream beds, these dome-shaped drifts may not be very large or very thick; on larger segments, they may form one large dome, or several, all, or some, very thick,—in cases even becoming small ice-caps. Thus there may be every gradation from small dome-shaped drift to the great ice-cap of Greenland. If the winds that blow over vary considerably and rather uniformly in direction, the domes are somewhat symmetrical; if not, they slope gradually toward the windward side, and quite abruptly on the other. On the plateaus north of Foulke Fjord, the winds blow from almost all points of the compass, as often, almost, from one direction as another, and the drift slopes almost uniformly from the center to the whole peripheral edge; on Herbert Island, where the winds blow generally from the South, the dome slopes gently in that direction, while on the north side, the slope is abruptly precipitous. Very few of the tops of the plateaus are free from dome-shaped drifts; and many terraced moraines, deltas, and plains are covered by the same form.

The *piedmont* drifts are those that form along the cliffs on the windward sides of valleys, fjords, and straits, on the lee sides of capes, peninsulas, and islands. They are formed from the snow that comes drifting over the lands back of the cliffs, and piles up on the talus slopes below, at the foot of the cliffs. Thus, both sides of Foulke Fjord are bordered for almost nine months of the year by these piedmont drifts, those on the north side from the snow carried over by northerly winds, those on the south from the snow carried

over by southerly winds. In Inglefield Gulf, only the south side is thus bordered because the cliffs on that side are more continuous, and the winds carry the snow from the plateaus over in great quantities; whereas on the north side, more broken by rather large valleys, the winds are deflected down the valleys, and little, if any, snow is carried over. Similar differences occur in other fjords.

The *wedge* drifts which form in gullies and small gorges near the top of the cliffs are genetically related to the piedmont cliffs, and consequently are distributed in much the same manner. They, however, are included within limited areas, and though in places they may be considered continuous with, and part of, the piedmont drifts, in other places they are the only drifts formed, for all the snow is carried into the gorges and gullies by the winds which are deflected into them The character of the drifts is so closely a function of the topography, the direction of the wind, and the consistency of the show, that as any one of these factors changes in character, the drifts may also change In Grenville Bay, for instance, the south side is bordered by piedmont and wedge drifts, while the north side is almost bare of snow; and since the south side gradually changes its direction from northeast-southwest at its mouth, to a nearly due east-west direction toward its head, and the prevailing wind is a general south-by-westerly, a regular succession develops, from tiny wedge drifts near the mouth, to a full-fledged glacier at the head, a glacier heading in a cirque a mile from the coast.

As long a quiescent neve covers the ground, and protects it from changes in temperature and from weathering, little disintegration or degradation can take place. It is only when the snow melts that the work begins. The melting in North Greenland is not a rapid process. Even when the sun shines at its highest, the temperature of the air does not rise much above 55° F.; it is usually lower, though that of exposed soil and rocks may be considerably higher. The snow drifts melt rather slowly, fastest at their edges.

Each of the kinds of drifts described produces different effects when melting. The dome-shaped drifts on the level surfaces melt first at their peripheral edges. The water formed is very near 32° F., and freezes at every drop of temperature due to cloudiness or change of wind so that excessive frost action takes place at the margin and just beyond, with consequent breaking up and disintegration of the rock. Often, too, the water freezes on the side of the drift away from the low sun, even at noondays, thus increasing the freezing action. Just beyond the margin of the drift, the temperature of the water is a little higher, and solifluction sets in. The disintegration of the rock, and the movement of resulting material, progresses in toward the center of the snow-drift covered area, as the drift melts back. Horizontal solifluction and consequent altiplanation terraces so clearly defined by H. M. Eakin,[1] are the immediate effect, and these in time result in reducing the plaeau top, or other plain surface, to a quite level surface, constantly being extended in area, and lowered. The process has been so well described by

Mr. Eakin that I merely call attention to this phase dependent upon the melting of the dome-shaped drifts.

The piedmont drifts formed on the lee slopes, or at the foot of the lee cliffs, act somewhat differently. The melting edges are at the top of the drift, and at the bottom. At the top the process is a sapping one, cutting back the cliff; at the bottom solifluction is the dominant process, though generally there is also some direct transportation by excess surface water that does not seep through the soil. The drift melts down from the top, and back from the foot. F. E. Mathes,[2] in his discussion of the glacial sculpture of the Bighorn Mountains, illustrates a cross section of such a drift, and the direction of the erosive attack upon the cliff. From the lower edge of the cliff where solifluction begins, the movement of the soil may continue to the foot of the slope, in one continuous sheet, or it may progress in a series of steplike slopes, or sloping terraces, with crescentic terminal margins, like festoons. Throughout northern Greenland these piedmont drifts are numerous, and almost invariably they give rise to similar solifluction slopes. When they occur on both sides of a V-shaped valley they tend to grade the sides and build up the bottom until it becomes U-shaped, as Mathes has described.

The wedge drifts formed in gullies and small gorges near the tops of cliffs, while acting in the same way as the piedmont drifts, produce different results. When these wedge drifts melt, the sapping process mentioned in the piedmont drifts cuts back the sides and the head of the gully or gorge in such a way as gradually to give it the form of a segment of a circle, the depth and extent of the segment depending upon the amount of snow blown into it. In this way a typical cirque may be initiated. When the snowdrifts become so large that they do not melt during the summer, ice gradually forms and a glacier occupies the floor of the cirque; frequently, though, the snow all melts away during the summer and no ice is formed, yet the cirque-form continues and the process goes on. A cirque in which ice has played no part can usually be distinguished by its rough and uneven floor, not at all like the scoured floor of a cirque once containing a glacier. The *bergshrund* in these high latitudes does not play an important part in cirque formationas it apparently does farther south, even in those cirques in which glaciers are formed; in the cirques carved by nivation alone there is, of course, no bergshrund at all.

Nivation is unquestionably of prime importance in the development of some of the topographic forms of the Greenland coast, and plays no small part in the degradation of the high cliffs, and the grading of the slopes.

Solifluction as defined by J. G. Andersson[3] is the process by which masses of the regolith saturated with water (which may come from melting snow or rain), flow slowly from higher to lower ground. This saturated, semi-fluid substance, not at all assorted as to size of fragments, moves along in much the same way as a glacier. H. M. Eakin[1] defined the process of solifluction as the migration of detritus under the thrust and heave of frost action. He

recognized and described several types of soil movement and resultant topographic forms.

In northwest Greenland, solifluction is closely connected with nivation. For it is under conditions best suited to nivation that soil flow is best developed as a transporting agency. If precipitation be in the form of rain, most of the water flows away as surface runoff and its chief work is then the characteristic ordinary stream action. But if precipitation be in the form of snow—as it is in northern Greenland—which melts rather slowly and gradually, little of the water flows away on the surface. Most of it seeps into the ground, saturates it, and forms a more or less pasty mass according to the relative proportions of soil and water. The presence of an ice-table, in that it effectually prevents the seepage of water below the depth of the ice, facilitates soil flow. Thus, perhaps, the principal conditions necessary to solifluction are snowfall, with gradual melting of the snow, and an ice-table to prevent, or at least retard, the seepage of water deep into the ground.

Several forms of solifluction occur in Greenland, including probably all that have been observed elsewhere. Distinction should be made between solifluction which causes progressive motion of surface material such as results in altiplanation terraces, solifluction slopes, and soil streams or soil glaciers; and that which causes only circulatory movement such as may result in 'polygon-boden.' It is the first of these forms of solifluction which is one of the most important important transporting agencies in northern Greenland, and which has produced there land forms similar to those described by Eakin in Alaska, and by Andersson and others elsewhere. The other of these forms is also generally prevalent in Greenland, but while it is an active agent of movement contributory to the breaking up and degradation of the detritus, it is not so important as a transporting agent.

Throughout northern Greenland, every land area free of ice and snow during the short summer, exhibits the solifluction slopes and altiplanation terraces described by Eakin from Alaska. Both on the slopes and on the plateaus, the terraces resulting from solifluction are every where conspicuous. In northwestern Greenland, particularly, solifluction of these types is a most important transporting agency; the removal of detritus resulting from nivation, freezing and insolation, to the few torrential streams that bear it onward to the sea, is quite dependent upon solifluction. In many valleys the streams at the bottom of the valleys are not nearly large enough to remove the detritus brought down by solifluction, and the valley fast fills up, with lakes in the depressions, behind the dams of more abundant, or faster moving, detritus. On the gentler slopes, the rate of movement is not high, but on some of the steeper slopes the movement is rapid.

Though the type of solifluction resulting in solifluction slopes and altiplantation terraces is the dominant and most important type in northern Greenland, other types are very well represented. From this important type to rock slide on the one hand, and to circulatory movement that re-

sults in 'polygon-boden' on the other, every gradation of type of soil-flow may be found, and the combined results of their activities is a transportation of material as important as that of the streams and glaciers.

All the field evidence tends to show that nivation and solifluction, characteristic processes of disintegration and denudation under subarctic or arctic conditions, are of prime importance in the reduction of the high relief of northern Greenland.

[1] Eakin, H. M., *Washington, U. S. Geol. Survey, Bull.* 631, p. 76, 1916.
[2] Mathes, F. E., *Washington, U. S. Geol. Survey, 21st Ann. Rep.*, p. 181, 1899–1900.
[3] Andersson, J. G., *Chicago, J. Geol., Univ. Chicago*, **14**, 1906, p. 91.

ON THE α-HOLOMORPHISMS OF A GROUP

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The term α-holomorphism was introduced by J. W. Young to denote a simple isomorphism of a group G with itself which is characterized by the fact that each operator of G corresponds to its α^{th} power.[1] A necessary and sufficient condition that an abelian group of order g admits an α-holomorphism is that α is prime to g, and J. W. Young proved in the article to which we referred that when a non-abelian group admits an α-holomorphism the $(\alpha-1)^{th}$ power of each of its operators is invariant under the group and the group admits also an $(\alpha - 1)$-isomorphism. Moreover, these conditions are sufficient for the existence of an α-holomorphism.

The object of the present note is to furnish a complete answer to the following question: For what values of α is it possible to construct non-abelian groups which admit separately an α-holomorphism? It will be proved that no such group is possible when α is either 2 or 3, but that for every other positive integral value of α there is an infinite system of non-abelian groups each of which admits an α-holomorphism.

The fact that every group which admits a 2-holomorphism is abelian results directly from a theorem noted in the first paragraph of this article. If a non-abelian group G admits a 3-holomorphism we may represent two of its non-commutative operators by s_1, s_2, and note that as a result of this holomorphism the two dependent equations

$$s_1^3 s_2^3 = (s_1 s_2)^3, \qquad s_1^2 s_2^2 = (s_2 s_1)^2$$

must be satisfied. Since s_1^2 and s_2^2 are invariant under G it results directly from the latter equation that $s_1 s_2 = s_2 s_1$, and hence the assumption that s_1 and s_2 are non-commutative led to a contradiction. That is, *if a group admits a 3-holomorphism it must be abelian.*

We shall now prove that when p is any odd prime number it is possible to construct a non-abelian group whose order is of the form p^m and which admits a $(1 + kp)$-holomorphism, k being an abitrary positive integer. Suppose that k is divisible by $p^{\beta-1}$ but not by p^β. Hence $1 + kp = 1 + hp^\beta$, where h is prime to p. Let t be an operator of order p which transforms an operator s of order $p^{\beta+1}$ into its $(1 + hp^\beta)^{th}$ power. It will be proved that t transforms each operator of the non-abelian group G of order $p^{\beta+2}$ which is generated by s and t into its $(1 + hp^\beta)^{th}$ power.

This proof is an almost direct consequence of the two dependent equations[2]

$$(st)^p = s^p, \quad (st)^{hp^\beta} = s^{hp^\beta}$$

In fact, from these equations it results that t transforms $s^{\alpha_1}t^{\beta_1}$ and s^{α_1} into the same powers. If we form the direct product of the group G just constructed and any abelian group of type $(1,1,1, \ldots)$ we clearly obtain another non-abelian group which is such that t transforms each of its operators into a $(1 + kp)$-holomorphism. The group G can therefore be used to construct an infinite system of groups each of which admits such a holomorphism.

To prove the theorem under consideration it is desirable to note that it is possible to construct a non-abelian group whose order is of the form 2^m and which admits a $(1 + 2^\gamma)$-holomorphism whenever $\gamma > 2$. In fact, if s is an operator of order $2^{\gamma+1}$ and if t is an operator of order 2 which transforms s into its $(1 + 2^\gamma)^{th}$ power the non-abelian group of order $2^{\gamma+2}$ which is generated by s and t will clearly satisfy the required condition. Moreover, each one of the infinite system of groups obtained by forming the direct product of the group just constructed and an abelian group of order 2^i and of type $(1,1,1,\ldots)$ must likewise satisfy this condition.

It is now easy to establish the general theorem noted in the second paragraph. To construct a non-abelian group which admits an α-holomorphism, $\alpha > 3$, it is only necessary to consider the factors of $\alpha - 1$. When $\alpha - 1$ is of the form 2^m any one of the groups described in the preceding paragraph satisfies the condition in question. When $\alpha - 1$ is not of this form let p be any one of its odd prime divisors and suppose that $\alpha - 1$ is divisible by p^β but not by $p^{\beta+1}$. Hence α is of the form $1 + hp^\beta$ considered above and it has been proved that *whenever $\alpha > 3$ it is possible to construct an infinite system of groups such that each group of this system admits an α-holomorphism.*

[1] J. W. Young, *New York, Trans. Amer. Math. Soc.*, 3, 1902, (186).

[2] Miller, Blichfeldt and Dickson, *Theory and Applications of Finite Groups*, Wiley, New York, 1916, p. 108.